FISH & RICHARDSON P.C.

Frederick P. Fish
1855-1930

W.K. Richardson
1859-1951

4225 Executive Square
Suite 1400
La Jolla, California
92037

Telephone
619 678-5070

Facsimile
619 678-5099

Web Site
www.fr.com

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Assistant Commissioner for Patents
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Presented for filing is a new provisional-to-utility patent application of:

Applicant: ERIC R. FOSSUM; ALEXANDER I. KRYMSKI; ROGER A. PANICACCI AND CHRISTOHER CLARK
Title: DIGITAL EXPOSURE CIRCUIT FOR AN IMAGE SENSOR

Enclosed are the following papers, including all those required to receive a filing date under 37 CFR §1.53(b):

	Pages
Specification	9
Claims	7
Abstract	1
Declaration	2
Drawing(s)	5

Enclosures:

- Small entity statement. This application is entitled to small entity status.
- Assignment cover sheet and an assignment, 2 pages, and a separate $40.00 fee.

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Deborah Dean

- Postcard.

Under 35 USC §119(e)(1), this application claims the benefit of prior U.S. provisional application 60/082,793, filed April 23, 1998.

Basic filing fee	$ 380.00
Total claims in excess of 20 times $9.00	9.00
Independent claims in excess of 3 times $39.00	0.00
Multiple dependent claims	0.00
Total filing fee:	$ 389.00

A check for the filing fee is enclosed. Please apply any other required fees or any credits to deposit account 06-1050, referencing the attorney docket number shown above.

If this application is found to be INCOMPLETE, or if a telephone conference would otherwise be helpful, please call the undersigned at 619/678-5070.

Kindly acknowledge receipt of this application by returning the enclosed postcard.

Please send all correspondence to:

Scott C. Harris
Fish & Richardson P.C.
4225 Executive Square, Suite 1400
La Jolla, CA 92037

Respectfully submitted,

Scott C. Harris
Reg. No. 32,030

Enclosures

ATTORNEY DOCKET NO. 08305/035001

Applicant or Patentee: Eric R. Fossum, et al.
Serial or Patent No.:
Filed or Issued: April 23, 1999
For: DIGITAL EXPOSURE CIRCUIT FOR AN IMAGE SENSOR

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) and 1.27(c)) - SMALL BUSINESS CONCERN

I hereby declare that I am

[ ] the owner of the small business concern identified below:
[X] an official of the small business concern empowered to act on behalf of the concern identified below:

Name of Small Business Concern: Photobit Corporation

Address of Small Business Concern: 135 North Los Robles Avenue, 7th Floor; Pasadena, CA 91101

I hereby declare that the above identified small business concern qualifies as a small business concern as defined in 13 CFR 121.12, and reproduced in 37 CFR 1.9(d), for purposes of paying reduced fees to the United States Patent and Trademark Office, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees of the business concern is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either, directly or indirectly, one concern controls or has the power to control the other, or a third party or parties controls or has the power to control both.

I hereby declare that rights under contract or law have been conveyed to and remain with the small business concern identified above with regard to the invention, entitled DIGITAL EXPOSURE CIRCUIT FOR AN IMAGE SENSOR by inventor(s) ERIC R. FOSSUM; ALEXANDER I. KRYMSKI; ROGER A. PANICACCI; and CHRISTOPHER CLARK described in

[X] the specification filed herewith.
[ ] application serial no. , filed .
[ ] patent no. , issued .

If the rights held by the above identified small business concern are not exclusive, each individual, concern or organization having rights to the invention is listed below and no rights to the invention are held by any person, other than the inventor, who would not qualify as an independent inventor under 37 CFR 1.9(c) if that person made the invention, or by any concern which would not qualify as a small business concern under 37 CFR 1.9(d), or a nonprofit organization under 37 CFR 1.9(e). NOTE: Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27)

Full Name: _____

Address: _____

[ ] INDIVIDUAL [ ] SMALL BUSINESS CONCERN [ ] NONPROFIT ORGANIZATION

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status when any new rule 53 application is filed or prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent on which this verified statement is directed.

Name: Claudine Antonino

Title: New Technology Manager

Address: 135 North Los Robles Avenue, 7th Floor; Pasadena, CA 91101

Signature: Claudine Antonino Date: 4/23/99

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APPLICATION

FOR

UNITED STATES LETTERS PATENT

TITLE: DIGITAL EXPOSURE CIRCUIT FOR AN IMAGE SENSOR

APPLICANT: ERIC R. FOSSUM; ALEXANDER I. KRYMSKI; ROGER A. PANICACCI AND CHRISTOHER CLARK

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Deborah Dean

DIGITAL EXPOSURE CIRCUIT FOR AN IMAGE SENSOR

Cross Reference to Related Applications

This application claims the benefit of the U.S. Provisional Application No. 60/082,793, filed on April 23, 1998.

Background of the Invention

CMOS active pixel sensors represent a digital solution to obtaining an image of an impinging scene. CMOS technology enables integrating electronics associated with the image sensing onto the chip. This includes, for example, one or more analog-to-digital converters on the chip, as well as timing and control circuitry.

One important feature of a well-defined image is an amount of exposure. Some cameras include automatic gain and exposure control. The automatic gain and exposure control determines if the image is underexposed or overexposed, and can adjust some

feature of the image acquisition to correct the exposure amount.

Existing CCD cameras select the exposure time based on some feature of the scene being imaged. Some cameras, for example, compute the average intensity over the entire pixel array. Other cameras compute the average intensity over a central area of the CCD. The average is often calculated by a digital signal processor which is separate from the CCD chip.

Summary of the Invention

The present system teaches a programmable threshold indicator based on accumulated and programmable measurements of image pieces. The digital image data stream is analyzed by the counting the number of samples within a given interval of intensities to form information indicating an image histogram. The sample count is compared with programmable thresholds.

Brief Description of the Drawing

FIG. 1 shows a basic block diagram;

FIG. 2 shows a flowchart of operation of a two-threshold embodiment;

FIG. 3 shows a point diagram of the FIG. 2 embodiment;

FIG. 4 shows a flowchart of a second, three-threshold embodiment;

FIG. 5 shows a point chart;

FIG. 6 shows exemplary circuitry for carrying out this embodiment; and

FIG. 7 shows results of simulation.

Description of the Preferred Embodiments

The inventors recognize that in some particular images, exposure control by simply computing the average of the image could produce disadvantageous results. For example, consider a scene of black and white stripes. Fifty percent of the image could be very bright, and the other fifty percent could be completely dark. The average is fifty percent which could be considered the correct exposure. Both image portions from the bright scene and the dark scene, however, could be poor.

The present system provides a programmable threshold indicator based on measurements of various portions of the image. A block diagram of the system is shown in Figure 1.

Active pixel image sensor 100 includes an array of units, e.g., rows and columns, of CMOS active pixels. Each preferably includes an in-pixel buffer transistor configured as a source follower, and an in-pixel row or column select transistor. The output of the sensor can be provided either single pixel at a time, or as a parallel group of pixel units 102 to the analog-to-digital converter 104. ADC 104 preferably produces an 8-bit output 106. The two to three most-significant bits of the analog-to-digital converter are usually enough to analyze intensity distribution.

The three most-significant bits 108 are coupled to pixel characterization elements 110. These detect whether the states of the three bit output 108 have a specified characteristics. When the states have the specified characteristics, the decoder produces an output. Counters 112 count the output, effectively counting the number of times that the bits are coincident with

the values. Therefore, the counters 112 keep a count, for each frame, of the number of samples which have specified values.

A number of thresholds are maintained by I/O register 114. Comparing elements 116 compare the counter outputs with the thresholds from the interface register. If one or more of these thresholds are exceeded, then decision block 118 produces a command to either increment or decrement the exposure: e.g., the shutter width or gain of image acquisition. This can be done frame by frame, or for a group of frames.

A first embodiment uses a two-threshold simple-scheme. This takes into account only the two most-significant bits. In this scheme, the relative number of data whose MsBs are " 11" are counted. The number of data in the lower half segment of the data scale (e.g. the most significant bit [MSB] is equal to 0) is also counted. The data " 11" is considered as being close to saturation. An exemplary threshold for the amount of that data can be thirty percent. Similarly, the tolerance for " dark" data, in which the MSB is zero, is restricted to be 75%. Step 202 detects if the first threshold in which both major bits are " 11" for more than thirty percent of the data. This is taken

as an overexposed condition at 204 and the integration time or gain is lowered. The second threshold is investigated at 210. If five percent of the data is dark (MSB is 0), the data is taken as underexposed data and the integration time or gain is increased.

The thresholds must be selected with an amount of hysteresis which is effective to avoid oscillations when the image has many contrasts i.e. between black and white. For example, the sum of the two percentages should exceed 100 percent.

FIG. 3 shows a bar graph with the overexposure/underexposure parameters. The point A in FIG. 3 is at an overexposed position. If more than 30 percent of the image is in this position, then the image is taken to be overexposed and the gain or integration time is lowered. Conversely, point B is in an underexposed position. If more than 75 percent of the image is in this position, then the image is taken to be underexposed.

A second embodiment which operates according to the flowchart of FIG. 4 uses a three threshold advance scheme. This takes only the two highest bits at the input to the indicator, as in the first system. However, this scheme uses three decoders

and three counters as shown in FIG. 1. This system counts: (a) the number of samples in which the upper bits are "11"; (b) the number of samples in which the most significant bit is "0"; and (c) the number of samples in which the upper bits are both "00". This provides more information about the image than the FIG. 2 system. This also enables adjusting the exposure/gain in two steps.

FIG. 4 shows a flowchart of the second embodiment. At step 410, the decision making process determines if the relative number of samples determined by a, in which both MsBs are "11" is more than 75 percent. If so, then the image is considered to be grossly overexposed. At step 406, the exposure/gain is decremented by a higher value H.

If the result of step 410 is No, step 420 tests if the relative number of samples is more than 30 percent. If so, the image is considered as being normally overexposed at 422. A tuning decrement T is applied at step 422 where T less than H.

If the relative number of sample c, the very dark pixels, is more than 75 percent at step 430, then the image is considered as

seriously underexposed. In this case, the exposure/gain is incremented by the higher value H at step 432.

Finally, if none of the other steps are true, the relative number of samples b, that is moderately dark pixels that are not very dark, are tested at 440. If this value is more than 75 percent detected at step 416, then the image is considered as moderately dark at 442. A tuning increment T is added to the exposure or gain.

This can be carried out on a frame by frame basis. These thresholds can also be programmable, to allow more bright or dark scenes. The programmable thresholds can be made by user manual intervention, or by an automatic intervention from the computer system.

FIG. 5 shows a bar chart showing the placement of the pixels within groups a, b, or c, similar to that in FIG. 3.

An example circuitry is shown in FIG. 6. It should be understood that this circuitry is exemplary only, and that other similar circuits could be easily formed using either a processor or hard wire gates using hardware definition language. Of

course, this operation could also be carried out using a programmed processor.

FIG. 7 shows results of a simulation using a simple test. The circuit signals maxed during the second frame as the number of 11 sample has exceeded 30 percent and min in the third frame as after two 00 counts has approached 75 percent of the total samples.

Although only a few embodiments have been disclosed above, other modifications are within the disclosed features.

For example, the system as described could be carried out using a processor or a digital signal processor. Preferably, however, all of the subjects in FIG. 1 are carried out on the same substrate.

What is claimed is:

1. An automatic exposure adjusting device, comprising:

an image sensor having an adjustment capability;

an analog to digital converter which produces a digital output indicative of an output of said image sensor;

a first counter which counts a number of overexposed parts of said image;

a second counter which counts a number of underexposed parts of said image;

a plurality of threshold detectors which compares counting results of said first and second counters with desired thresholds; and

a decision element, which makes a decision to either increase an exposure of said image sensor or decrease an exposure of said image sensor based on said relation with said threshold.

2. A device as in claim 1, wherein said image sensor includes a plurality of pixels, said analog to digital converter

produces its digital output indicative of each pixel, and further comprising a coincidence detector, which reviews only a predetermined number of most significant bits of said digital output.

3. A device as in claim 2, wherein said first counter counts a number of pixels whose most significant bits include ones.

4. A device as in claim 3, wherein said second counter counts a number of pixels in which said most significant bit includes a zero.

5. A device as in claim 3, in which said second counter counts a number of pixels whose most significant bit includes at least one zero.

6. A device as in claim 5, wherein said threshold detectors include values indicative of what percentage of the image can have underexposed or overexposed pixels, said decision

element increasing or decreasing said exposure based on said percentages.

7. A device as in claim 2, wherein there are two coincidence detectors representing relationships with two different thresholds, one of which is for an overexposed image and another of which is for an underexposed image.

8. A device as in claim 7, wherein said decision element reduces an exposure time for said overexposed image and increases the exposure time for said underexposed image.

9. A device as in claim 2, wherein there are at least three of said coincidence detectors detecting at least three different features including an overexposed image, an underexposed image, seriously underexposed image, and a seriously overexposed image.

10. A device as in claim 9, further comprising a threshold storing element, storing first and second increase and decrease

thresholds, an overexposed or underexposed image being increased or decreased by said first threshold, and the seriously over exposed or under exposed image being increased or decreased by said second threshold.

11. A device as in claim 1, wherein said image sensor includes an active pixel sensor with a plurality of pixels of CMOS image sensor, each pixel including an in-pixel buffer transistor and in-pixel selection transistor.

12. A device as in claim 1, wherein there is a first threshold for a seriously deficient image and a second threshold for a less seriously deficient image, said first and second thresholds collectively adding up to more than 100%.

13. A device as in claim 1, wherein said exposure is one of a shutter width or a gain of the image sensor.

14. An automatic exposure adjusting image sensor device, comprising:

an image sensor, including a plurality of adjustable photoreceptors, each photoreceptor defining a pixel of the image, and said image sensor having an adjustable exposure which when increased increases an amount of exposure, and when decreased, decreases an amount of exposure;

an analog to digital converter which obtains a analog output from said image sensor and produces a digital output indicative of said analog output to thereby produce a plurality of digital outputs for said plurality of pixels;

a pixel characterization element, investigating only certain most significant bits of at least a plurality of said digital outputs, to thereby characterize said pixel according to its exposure characteristic;

a counter element, which counts numbers of pixels characterized by said pixel characterization element and compares said count with certain thresholds; and

an image adjusting element, which adjusts said exposure based on said count.

15. A device as in claim 14, further comprising a memory storing said thresholds, and said memory is variable to change said thresholds.

16. A method of automatically determining exposure control for an image comprising:

obtaining a plurality of digital values, said plurality of digital values representing values of said pixels;

setting a variable threshold for overexposed pixels;

setting another variable threshold for underexposed pixels;

characterizing said digital values to determine if they represent overexposed pixels, normally-exposed pixels or underexposed pixels; and

if a number of overexposed pixels is greater than said threshold, then increasing an exposure and if the number of under exposed pixels is greater than said second threshold then decreasing the exposure.

17. A method as in claim 16, wherein said investigating comprises obtaining only a number of most significant bits of

said pixels and not all bits of said pixels and investigating said most significant bits.

18. A method as in claim 17, wherein an over exposed pixel is taken as one whose two most significant bits are "11".

19. A method as in claim 18, wherein an under exposed pixel is taken as one in which its most significant bit is zero.

20. A method as in claim 17, further comprising detecting seriously overexposed and underexposed pixels as well as moderately overexposed and moderately underexposed pixels.

21. A method as in claim 20, wherein said changing an exposure comprises changing the exposure by one amount for seriously overexposed or underexposed pixels and changing the exposure by another amount for less-seriously underexposed or overexposed pixels.

Abstract of the Disclosure

Automatic exposure adjusting device considers the image on a pixel-by-pixel basis. Each pixel is characterized according to its most significant bits. After the pixels are characterized, the number of pixels in any particular group is counted. That counting is compared with thresholds which set whether the image is over exposed, under exposed, and can optionally also determine if the image is seriously over exposed or seriously under exposed. Adjustment of the exposure is carried out to bring the image to a more desired state.

The block-diagram of the indicator is presented in Fig.1.

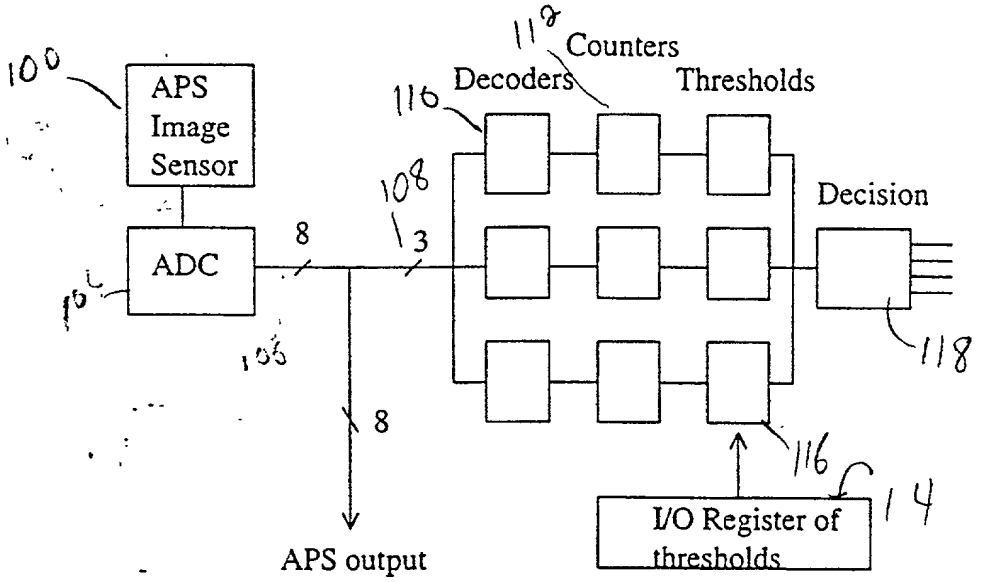


Fig.1. Block-diagram of indicator.

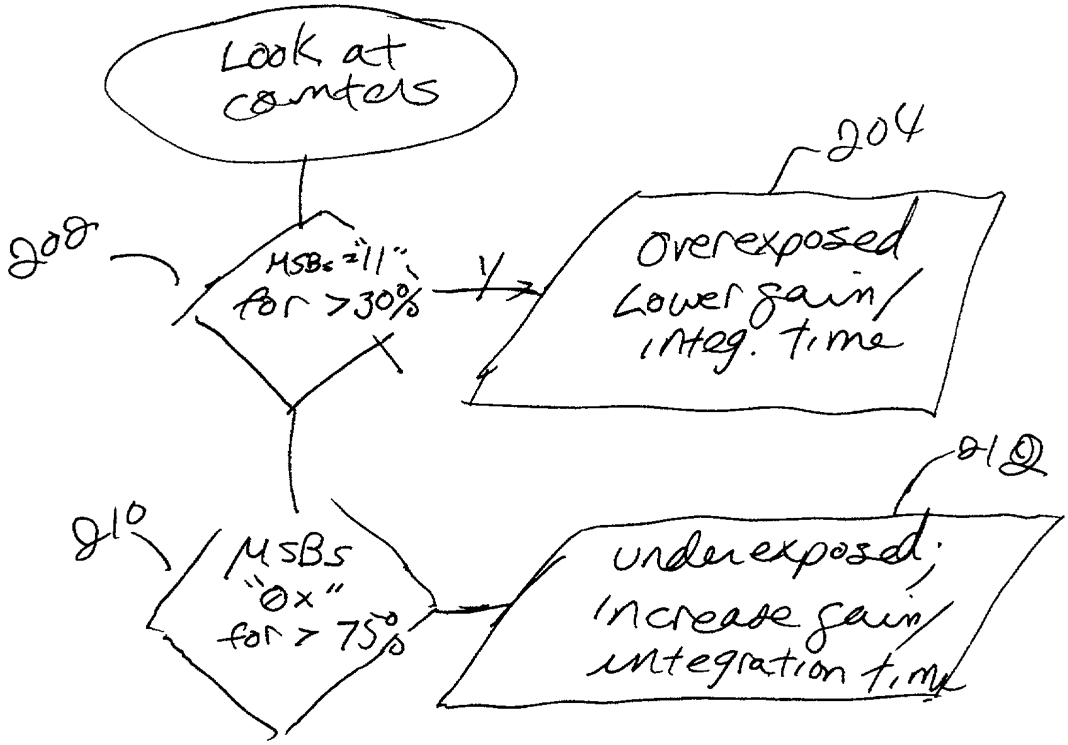
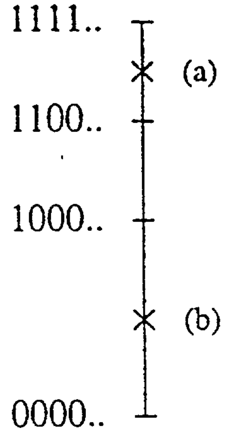

Look at counters
208
MSBs "11"
for >30%
Y
204
overexposed
Lower gain/
integ. time
210
MSBs
"0x"
for > 75%
212
underexposed;
increase gain/
integration time

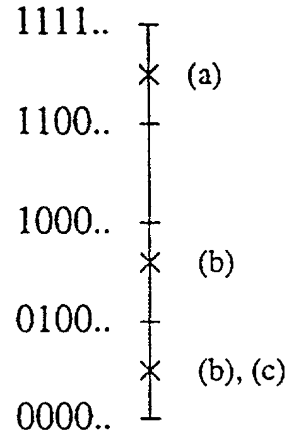
FIG 2



(a) >30% : overexposed

(b) >75% : underexposed

FIG 3



(a) >75% : grossly overexposed
(c) >75% : grossly underexposed
elsif (a) >30% : overexposed
elsif (b) >75% : underexposed

FIG. [illegible]

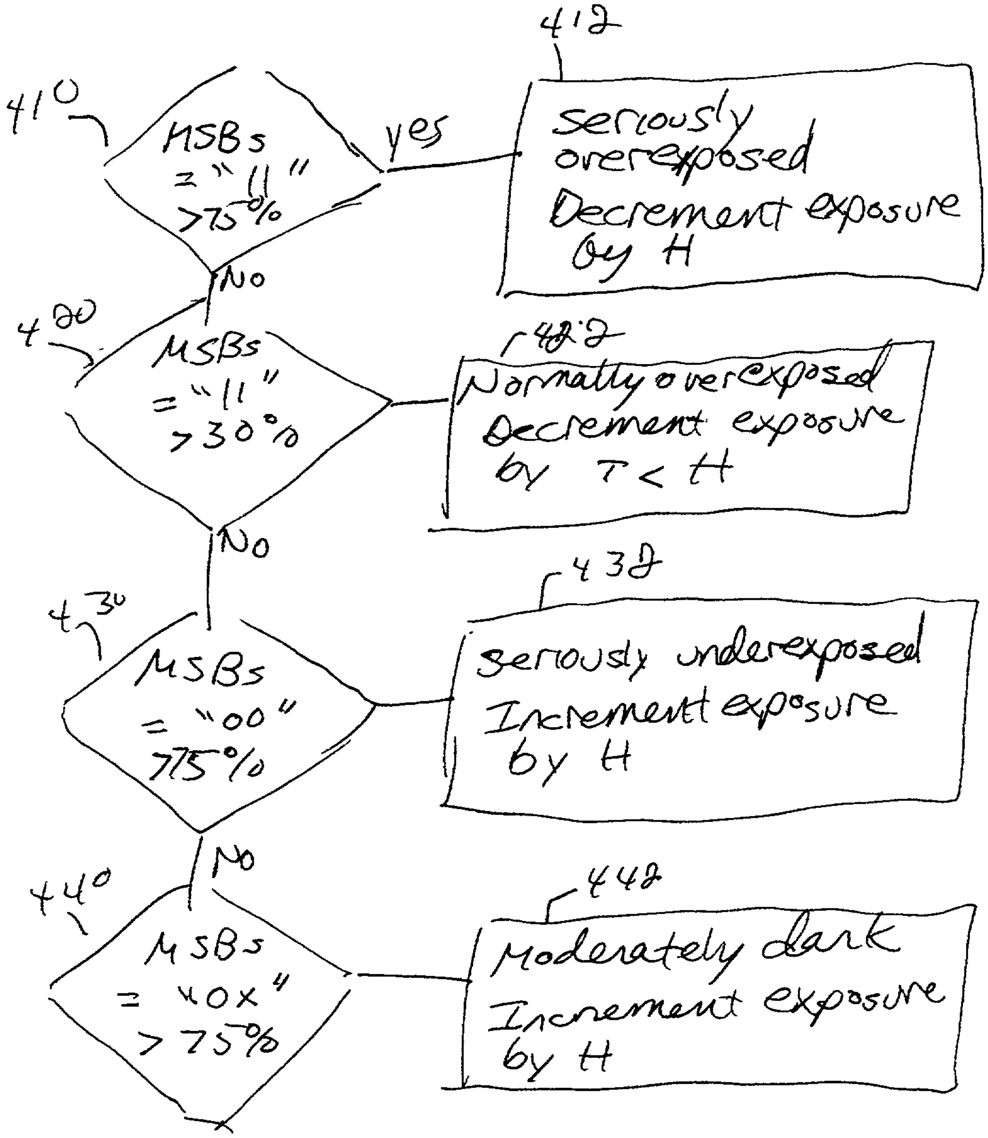

410
MSBs = "11" >75%
yes
412
seriously overexposed Decrement exposure by H
No
420
MSBs = "11" >30%
422
Normally overexposed Decrement exposure by T < H
No
430
MSBs = "00" >75%
432
seriously underexposed Increment exposure by H
No
440
MSBs = "0x" >75%
442
Moderately dark Increment exposure by H

FIG 4

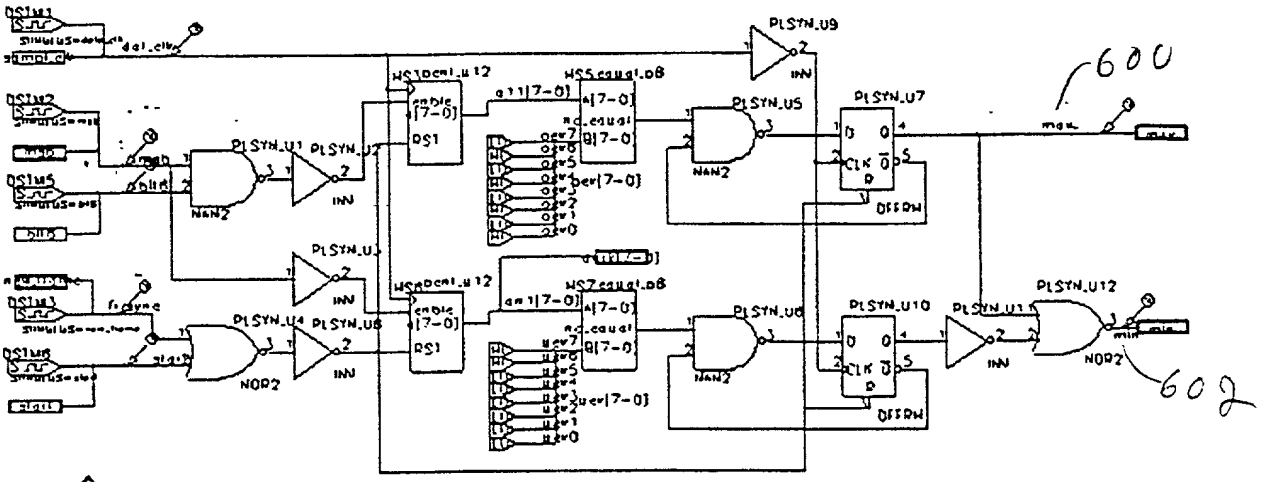


Fig. 6. Schematic of indicator, the circuit which makes decision if the image is overexposed, underexposed or normal (no output).

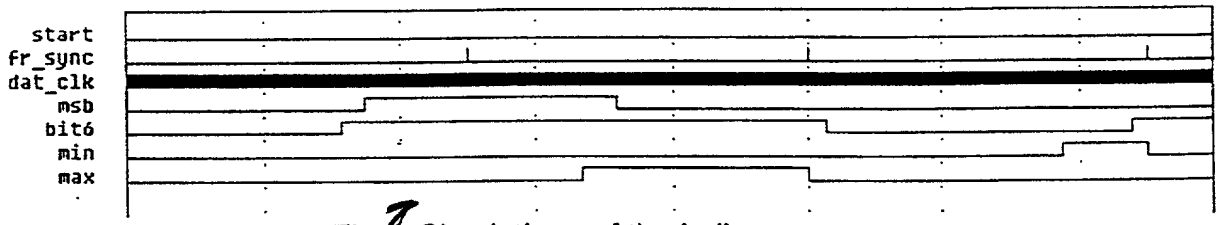


Fig. 7. Simulations of the indicator.

PATENT
ATTORNEY DOCKET NO: 08305/035001

COMBINED DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled DIGITAL EXPOSURE CIRCUIT FOR AN IMAGE SENSOR, the specification of which

■ is attached hereto.
☐ was filed on _____ as Application Serial No. _____
and was amended on _____.
☐ was described and claimed in PCT International Application No. _____
filed on _____ and as amended under
PCT Article 19 on _____.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose all information I know to be material to patentability in accordance with Title 37, Code of Federal Regulations, §1.56.

I hereby claim the benefit under Title 35, United States Code, §119(e)(1) of any United States provisional application(s) listed below:

U.S. SERIAL NO.	FILING DATE	STATUS
60/082,793	4/23/98	■ Pending ☐ Issued ☐ Abandoned

I hereby appoint the following attorneys and/or agents to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: Scott C. Harris, Reg. No. 32,030; ; William J. Egan, III, Reg No. 28,411; David L. Feigenbaum, Reg. No. 30,378; John F. Land, Reg No. 29,554; Ralph A. Mittelberger, Reg. No. 33,195; Hans R. Troesch, Reg. No. 36,950; John R. Wetherell, Jr., Reg. No. 31,678; Bing Ai, Reg. No. 43,312; and George C. Pappas, Reg. No. 35,065.

Address all telephone calls to Scott C. Harris at telephone number 619/678-5070.

Address all correspondence to Scott C. Harris, Fish & Richardson P.C., 4225 Executive Square, Suite 1400 , La Jolla, CA 92037.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patents issued thereon.

Full Name of Inventor: Eric R. Fossum

Inventor's Signature: _____ Date: 4-22-99

Residence Address: 5556 Pinecone Road, La Crescenta, CA 91214

Citizen of: US

Post Office Address: Same as residence

PATENT
Attorney Docket No. 08305/035001/98-05

COMBINED DECLARATION AND POWER OF ATTORNEY CONTINUED

Full Name of Inventor: Alexander I. Krymski
Inventor's Signature: A Krymski Date: 4/22/99
Residence Address: 2255 Montrose Ave. #15 Montrose, CA 91020
Citizen of: Russia
Post Office Address: Same as residence

Full Name of Inventor: Roger A. Panicacci
Inventor's Signature: Roger A. Panicacci Date: 4/23/99
Residence Address: 789 Portola Terrace, Los Angeles, CA 90042
Citizen of: US
Post Office Address: same as residence

Full Name of Inventor: Christopher Clark
Inventor's Signature: Christopher Clark Date: 4/23/99
Residence Address: 382 E. California Blvd, #307, Pasadena, CA 91106
Citizen of: US
Post Office Address: Same as residence

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